Neutron Scattering Studies of Photosynthetic Energy Transduction Complexes

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Neutron Workshop
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Funding: DOE-EFRC program

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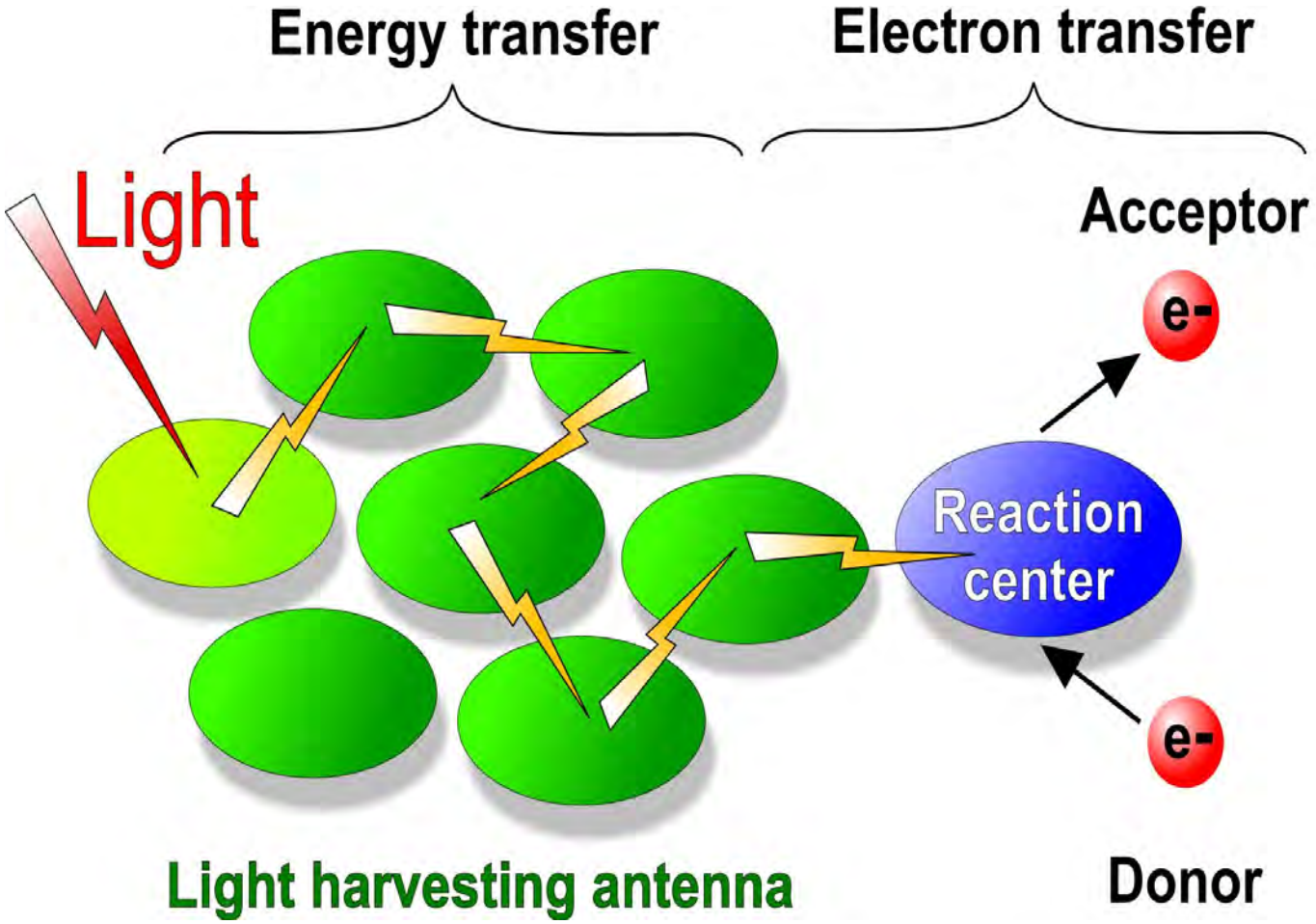
Photosynthesis- The Conversion of Light Energy into Chemical Energy

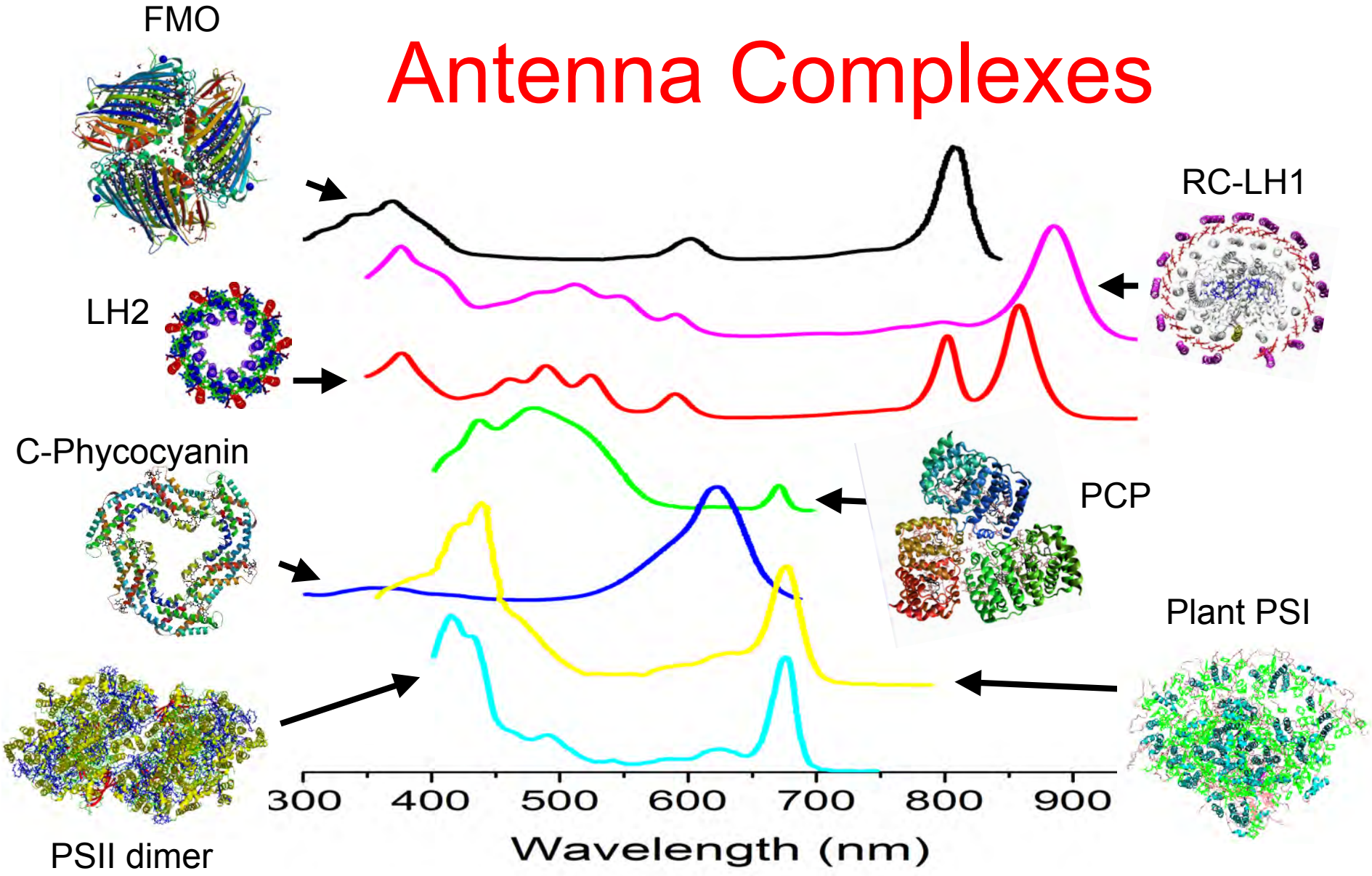
PS is the source of all our food and most of our energy resources on Earth

Photosynthetic Energy Storage



All PS organisms contain a light-gathering antenna system

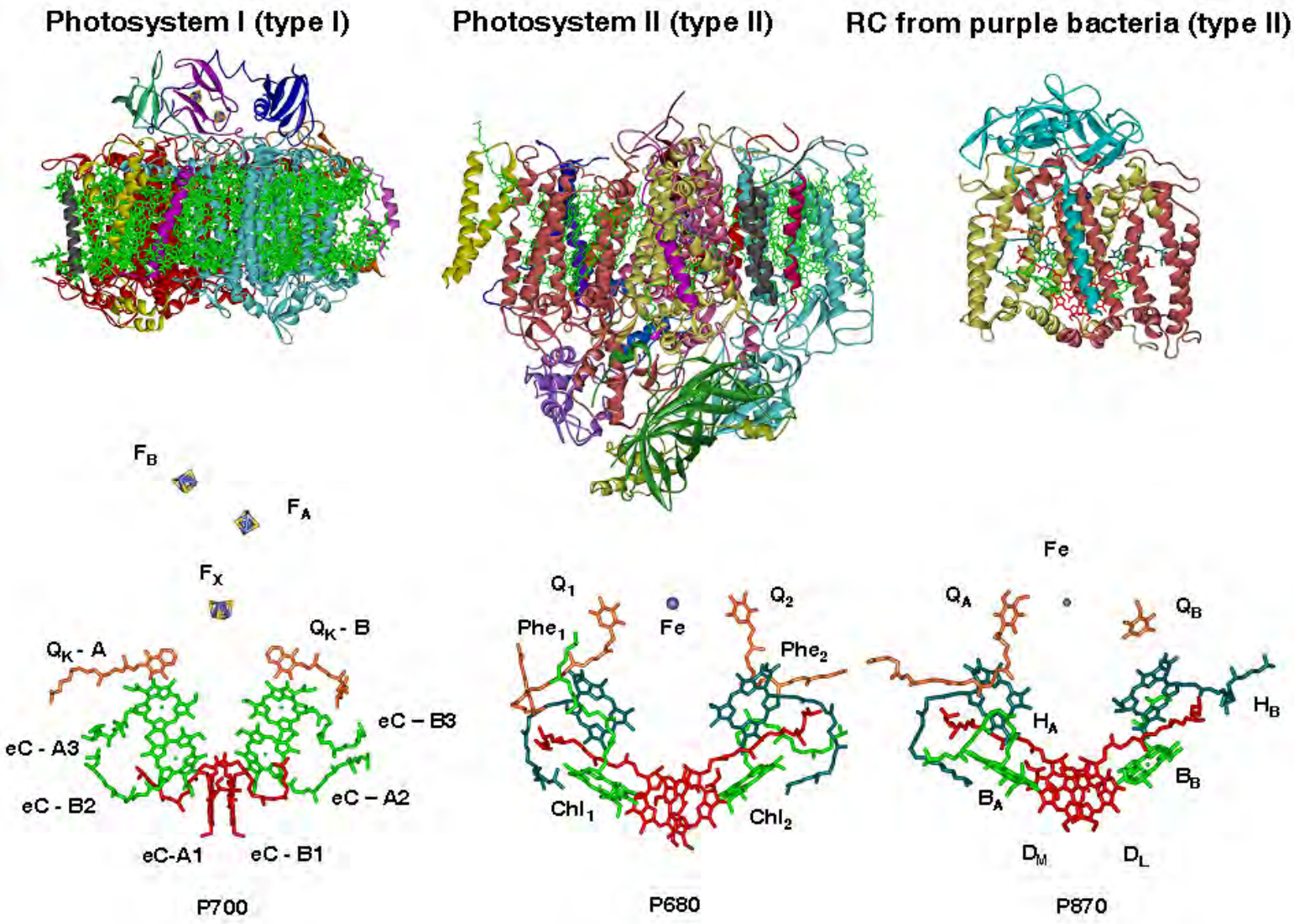
Antenna Complexes



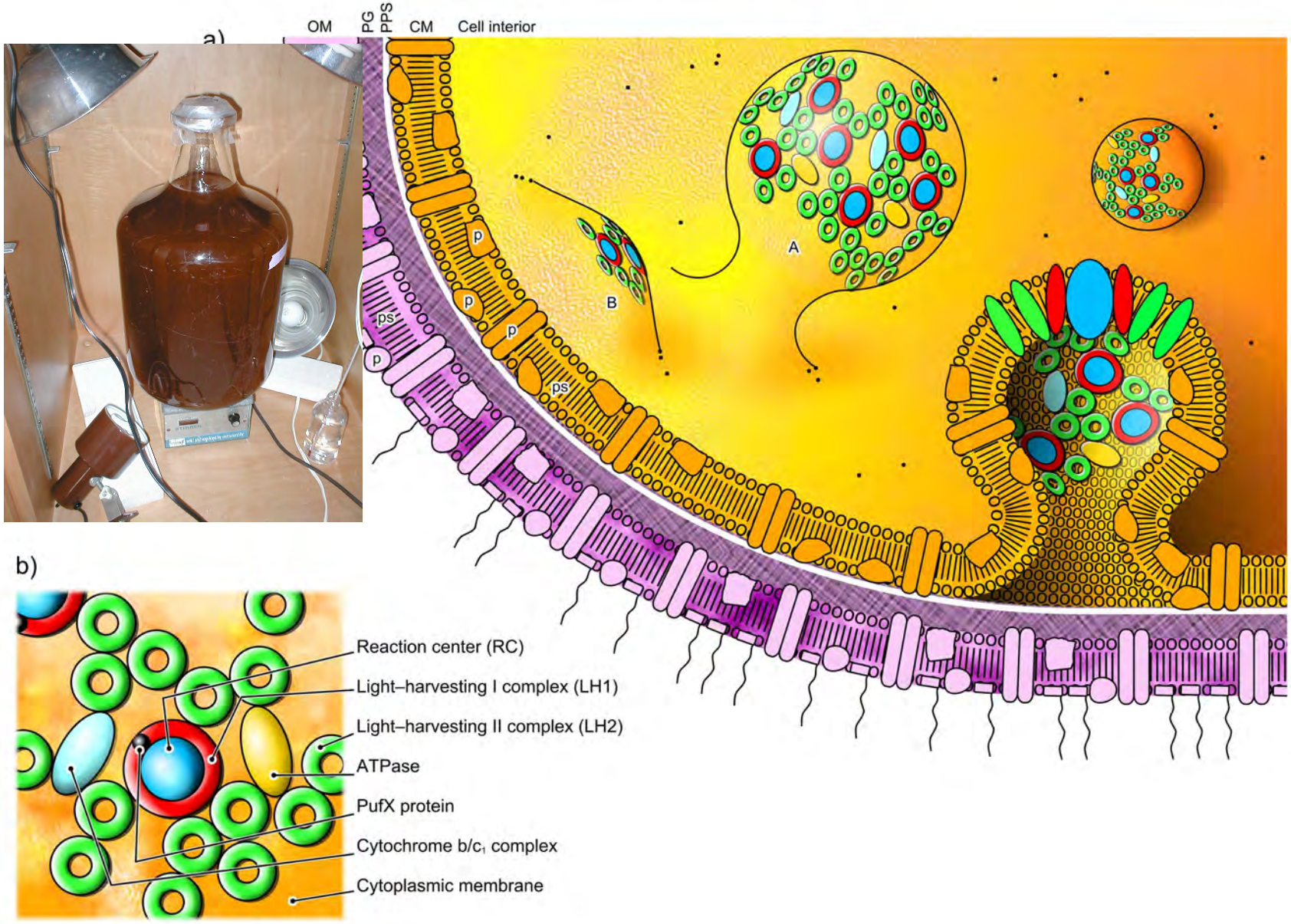
Extreme diversity of antenna systems strongly suggests multiple independent evolutionary origins

Aaron Collins 2010

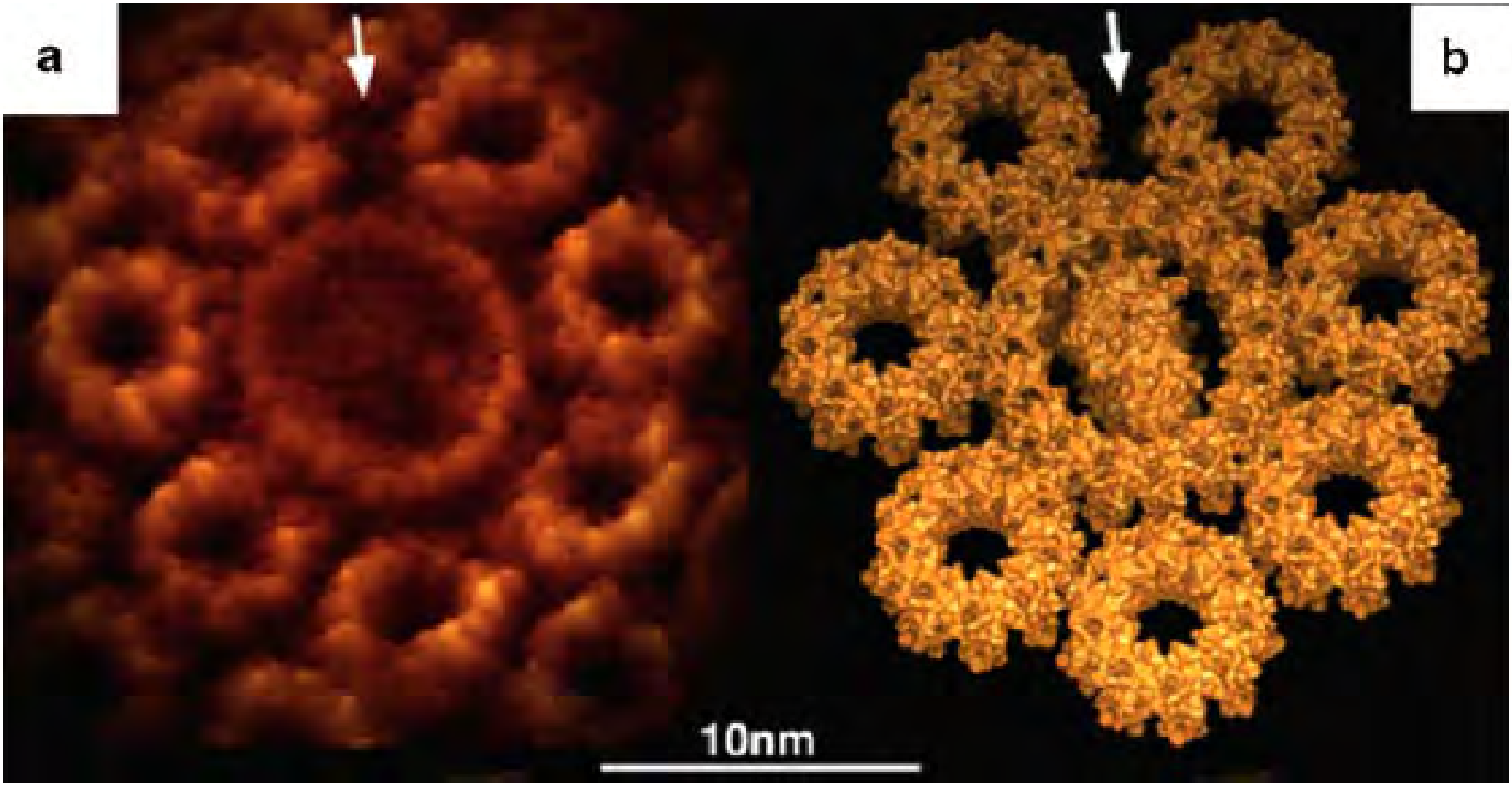
Photosynthetic Reaction Centers



Purple bacterial membrane



Purple Bacterial Membrane



Sturgis and Niederman 2008

Photosynthetic Antenna Research center (PARC)

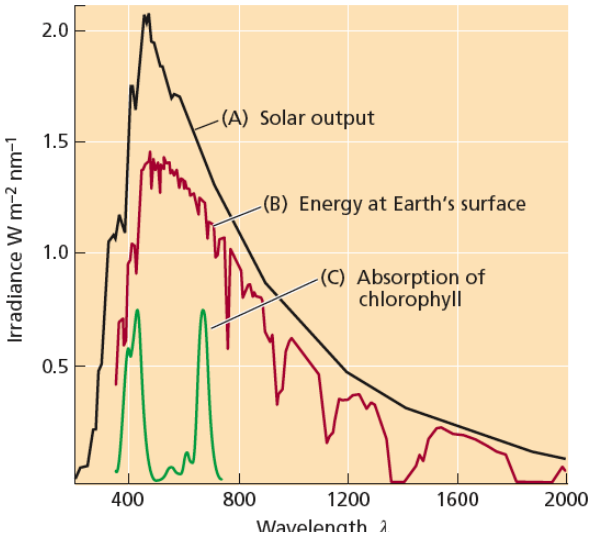
Objective: To understand the basic scientific principles that underpin the efficient functioning of the natural photosynthetic antenna system as a basis for man-made systems to convert sunlight into fuels.

- Washington University (Biology, Chemistry, EECE)
- Donald Danforth Plant Sci. Ctr.
- National Laboratories (Los Alamos, **Oak Ridge**, Sandia)
- US Universities (Pennsylvania, North Carolina State, California-Riverside)
- UK Universities (Glasgow, Sheffield)

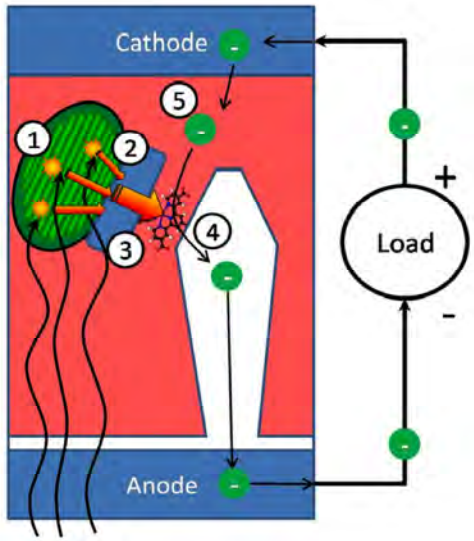
Funded by DOE EFRC

PARC Scientific Themes

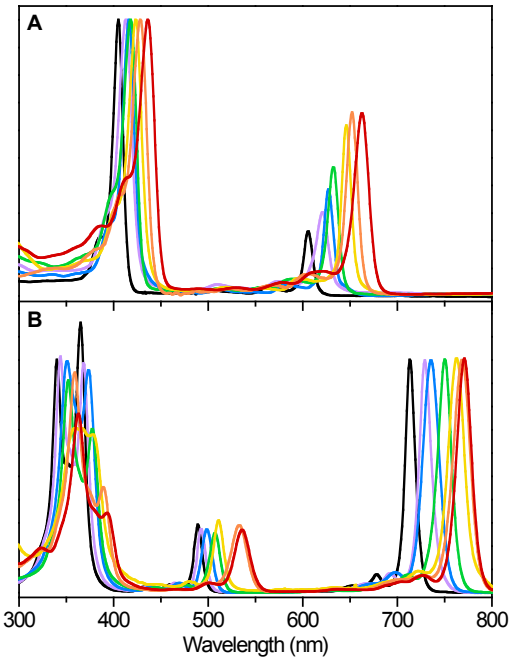
Natural Antennas: Structure and Efficiency



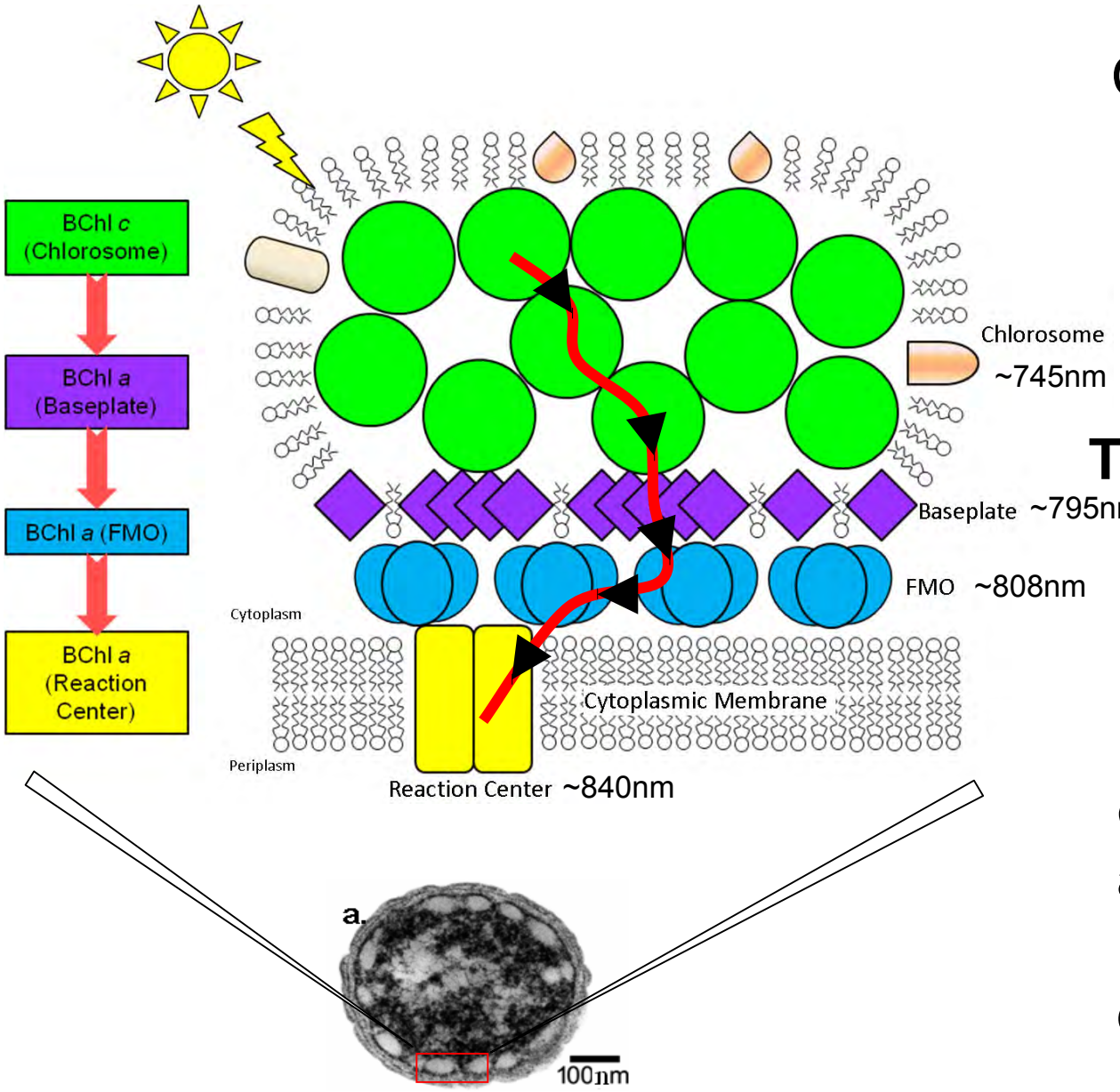
Biohybrid Antennas: Organization and Implementation



Bioinspired Antennas: Design and Characterization



Photosystem from Green Sulfur Bacteria



Chlorosome:

Length: 110–180 nm
Width: 40–60 nm
Height: 20-30 nm
Bchl *c/d/e*: ~ 200,000

Total mass ~10^8 Da

Functions at very low light intensity-- **one photon absorbed per pigment every eight hours!**

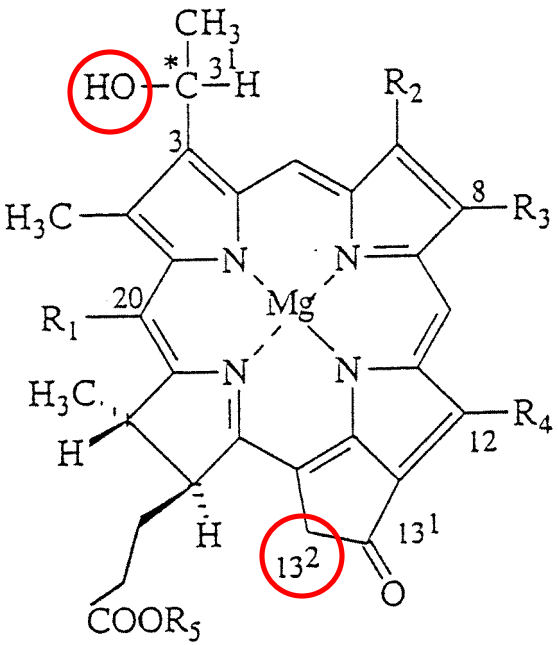
Chlorosome antenna complexes

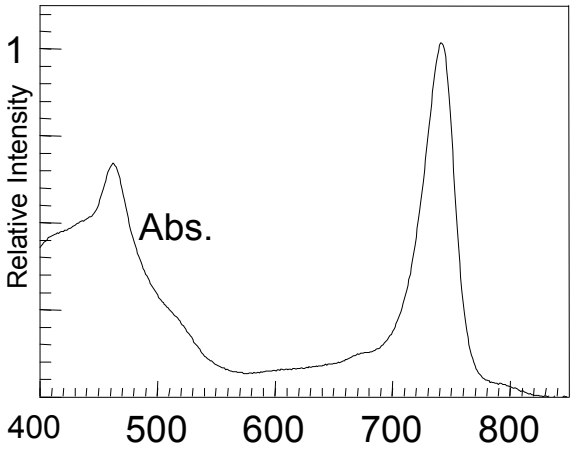
- Cells of green PS bacteria contain ~100 chlorosomes attached to the inside of the cell membrane
- Each chlorosome contains ~200,000 molecules of BChl *c* as well as carotenoid and small amounts of BChl *a* with only small amounts of protein

Martin Hohmann-Marriott

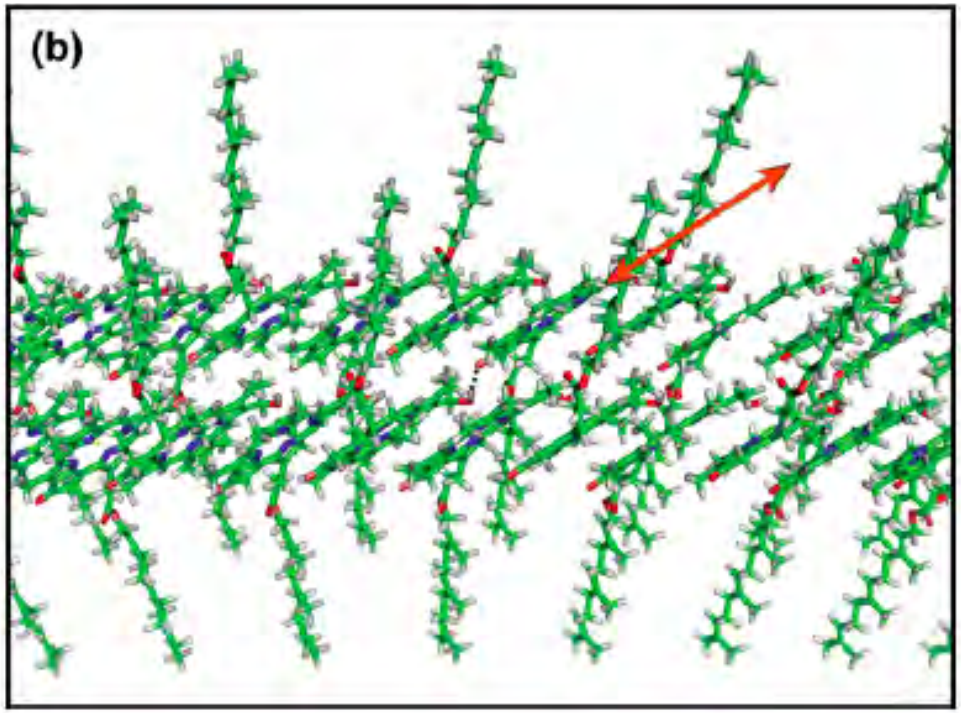
Chlorosome Bacteriochlorophyll Organization

Bchl *c,d or e*



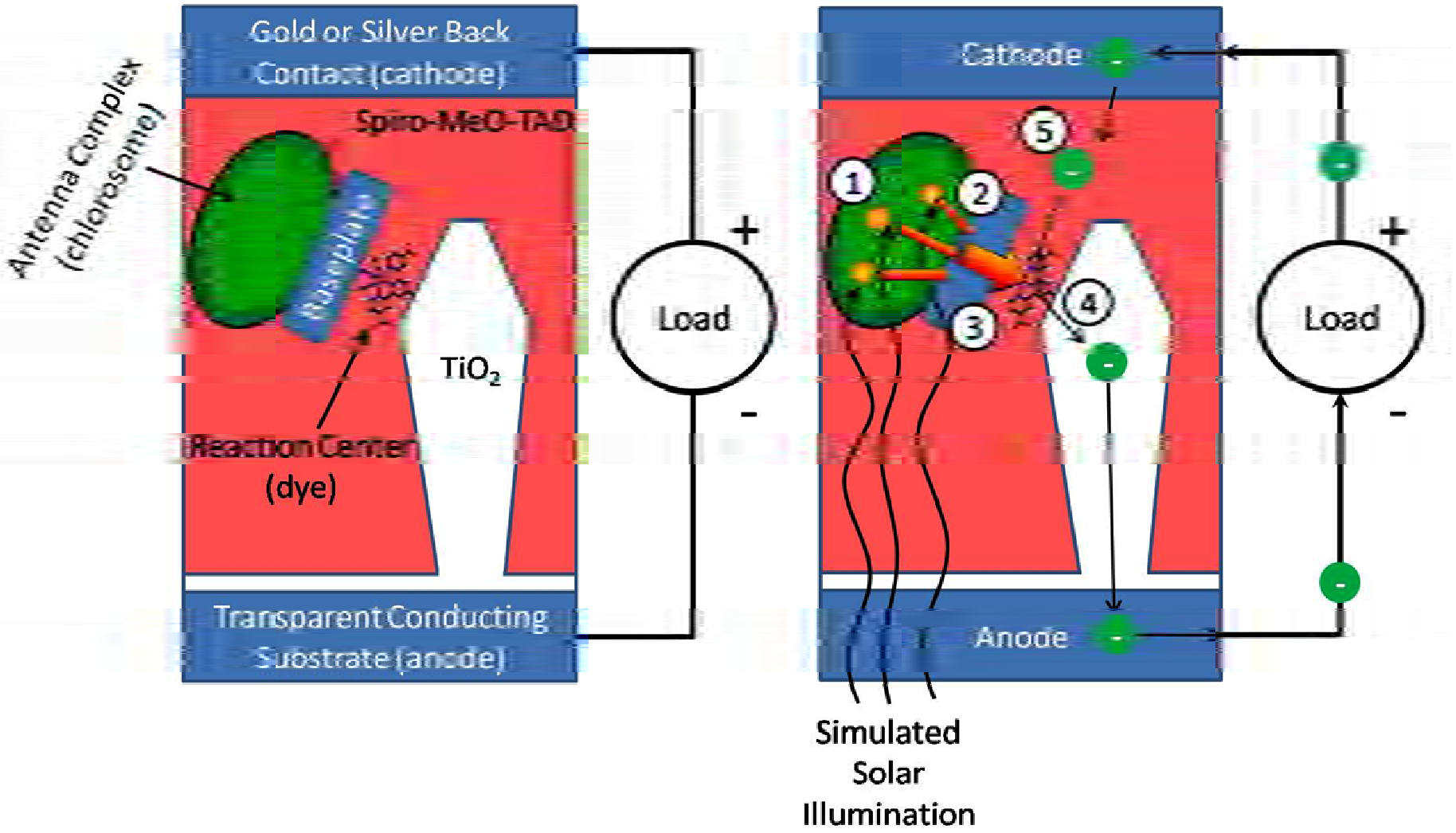


- No protein!
- Pigment oligomers
- Reversible self-assembly
- Similar to J aggregates

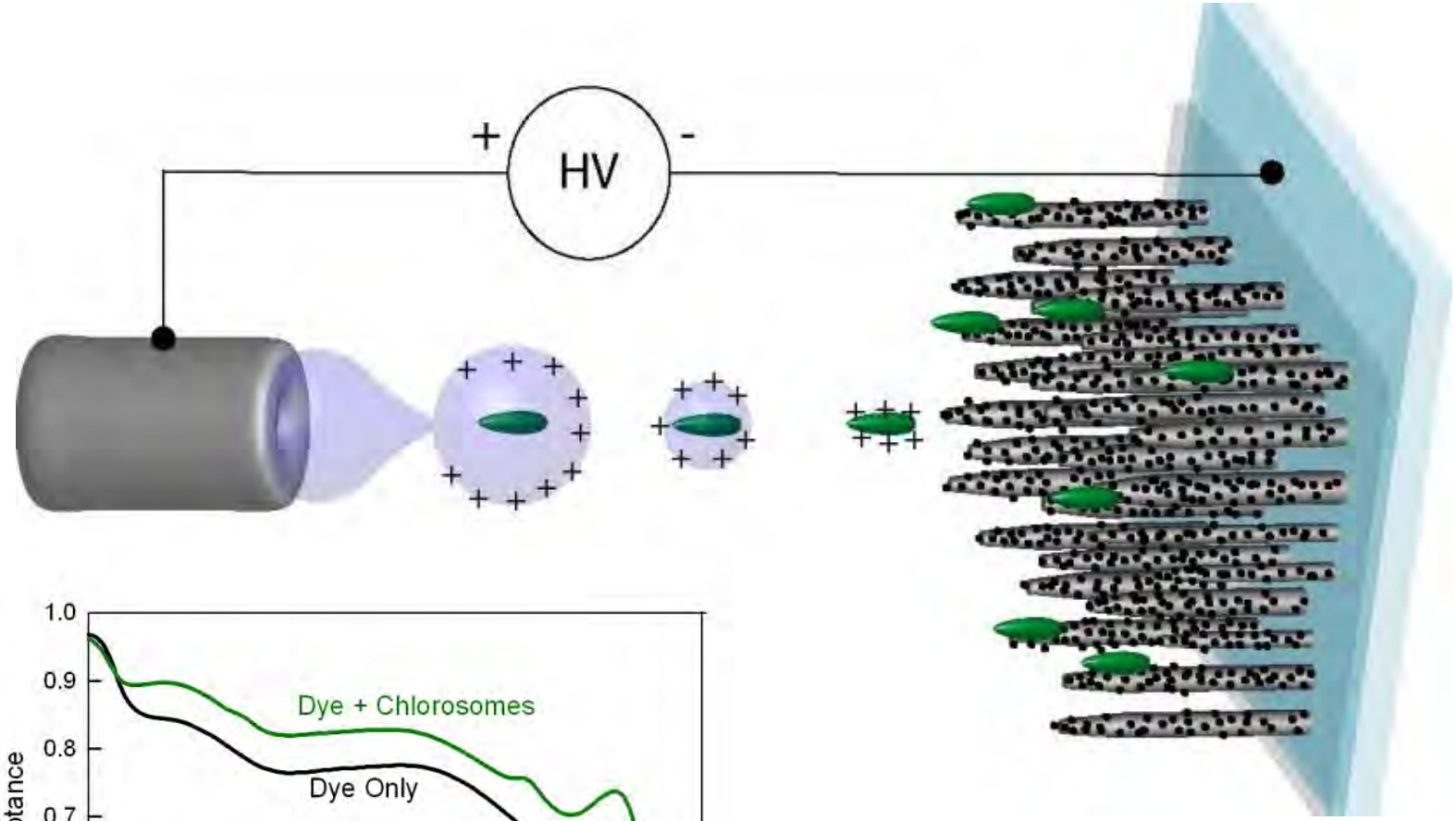


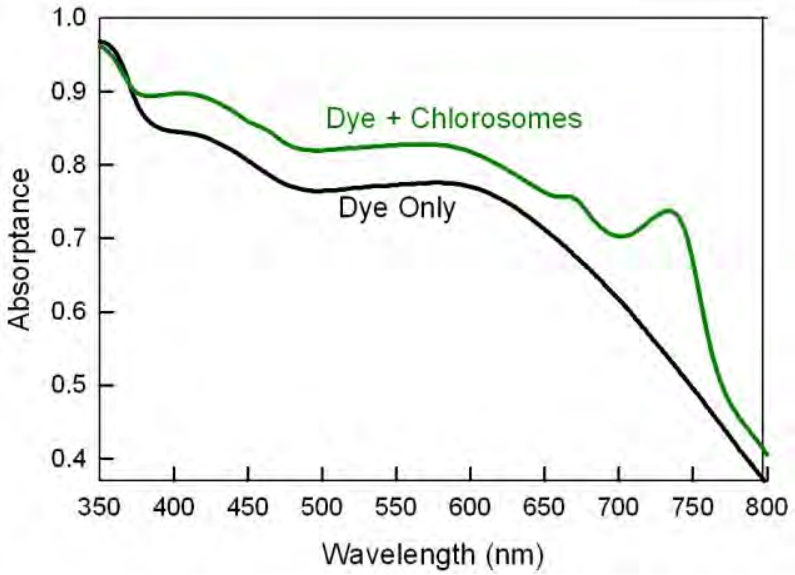
Oostergetel et al. *Photosynth. Res.* (2010)

Bio-hybrid solar cell

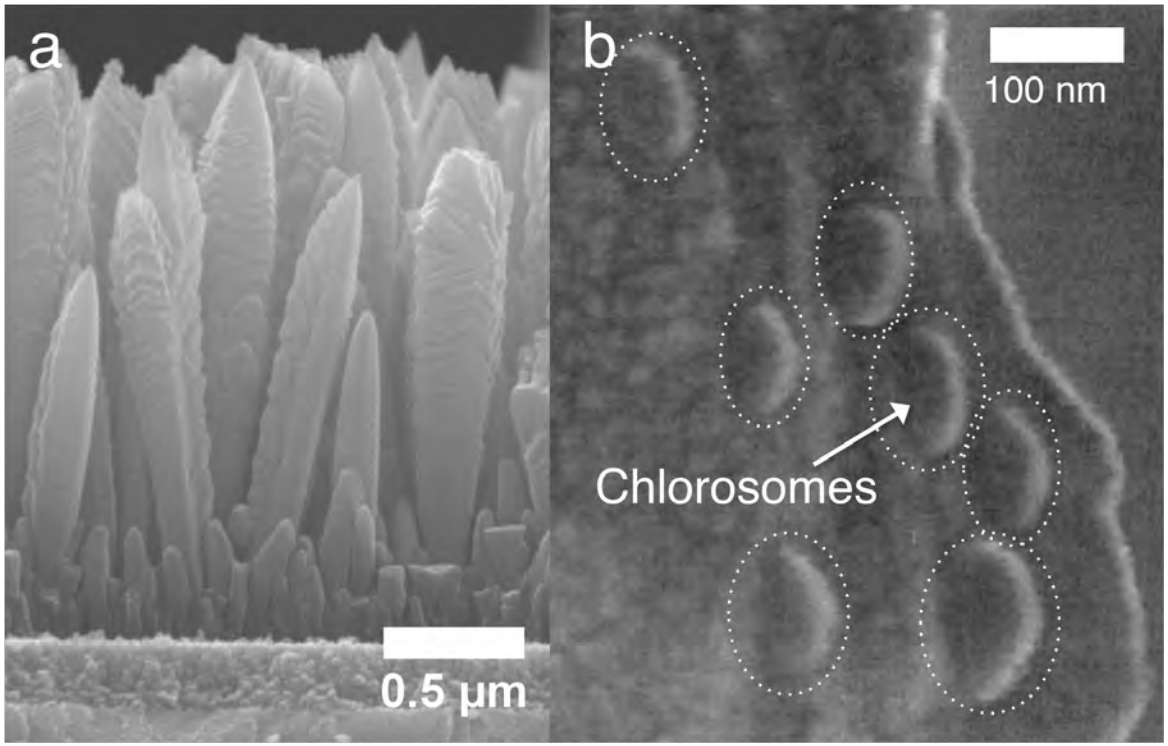


Electrospray Processing Steps

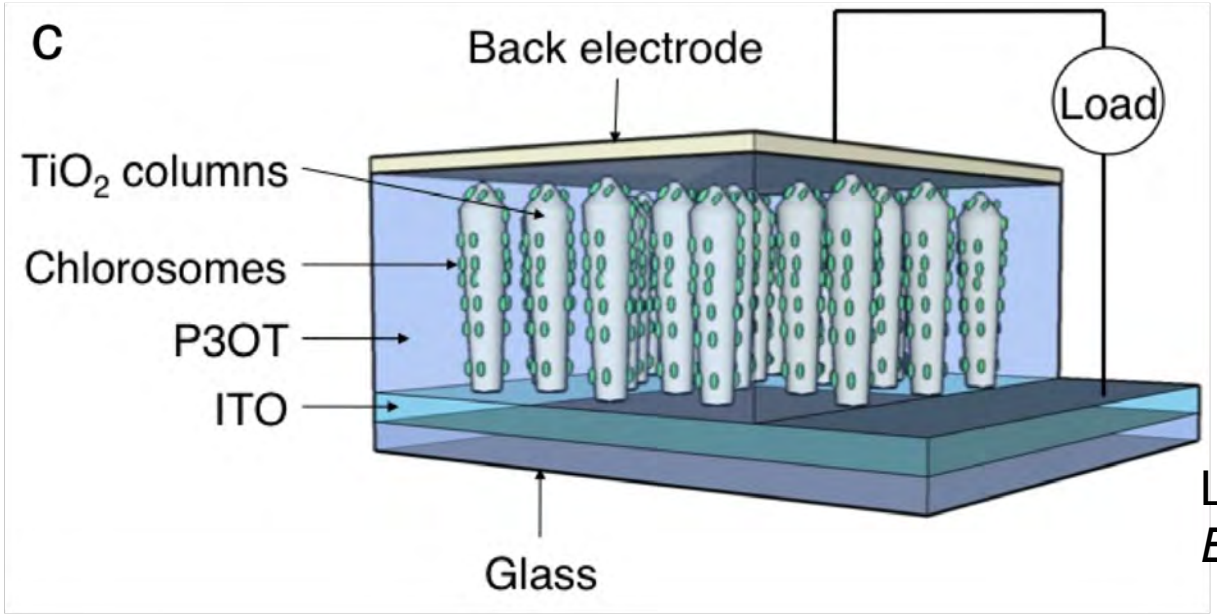




Chlorosomes are intact after deposition



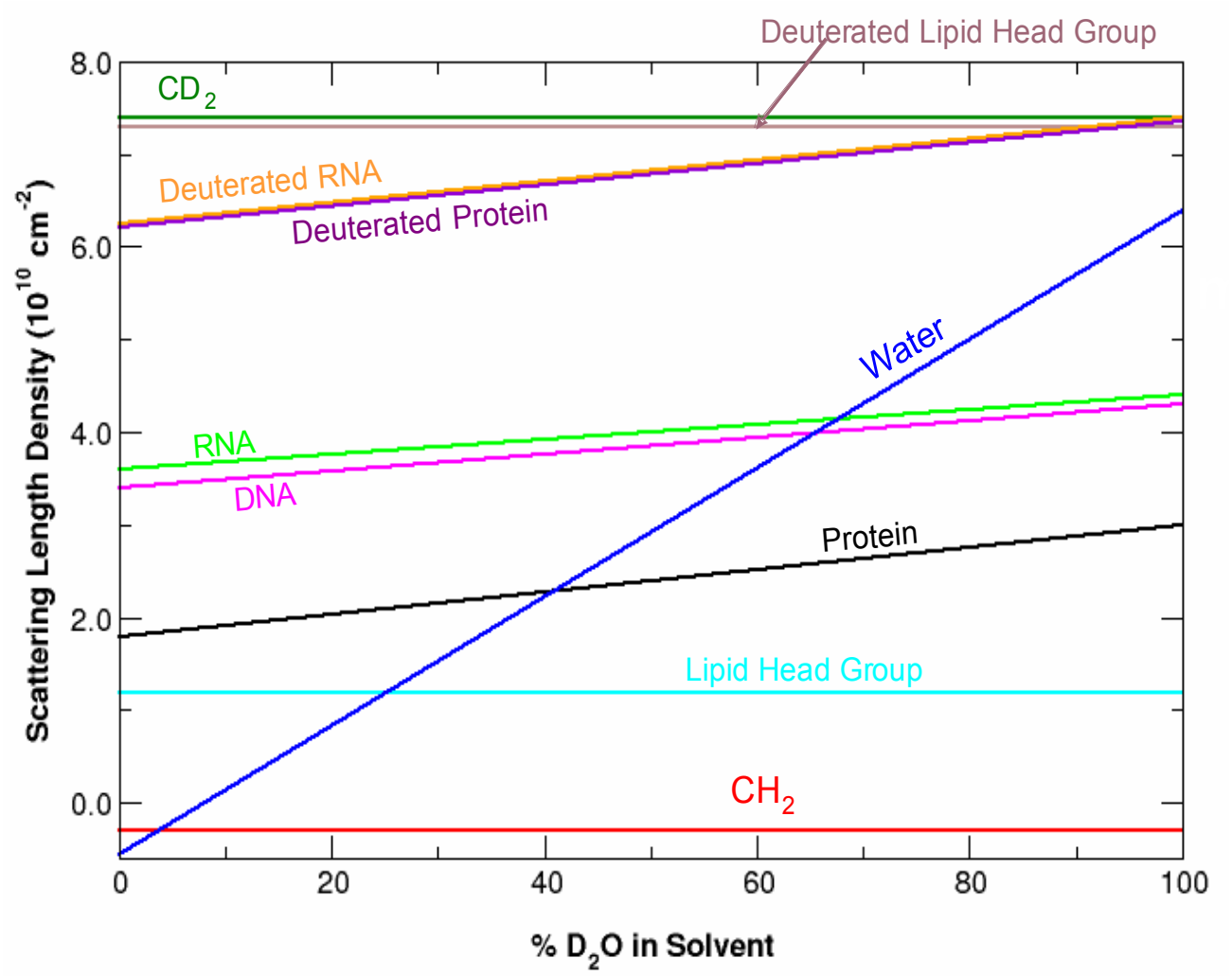
Microscopy images of nanostructured TiO_2 film and concept of a nano-bio device. **a**, TiO_2 columnar film deposited onto ITO coated glass by a flame aerosol reactor. **b**, Chlorosomes electrospray-deposited onto a columnar TiO_2 film. **c**, schematic cartoon of a novel nano-bio hybrid devices that incorporates whole chlorosomes (without RC) and nanostructured TiO_2 columns.



P3OT=poly octothiophene

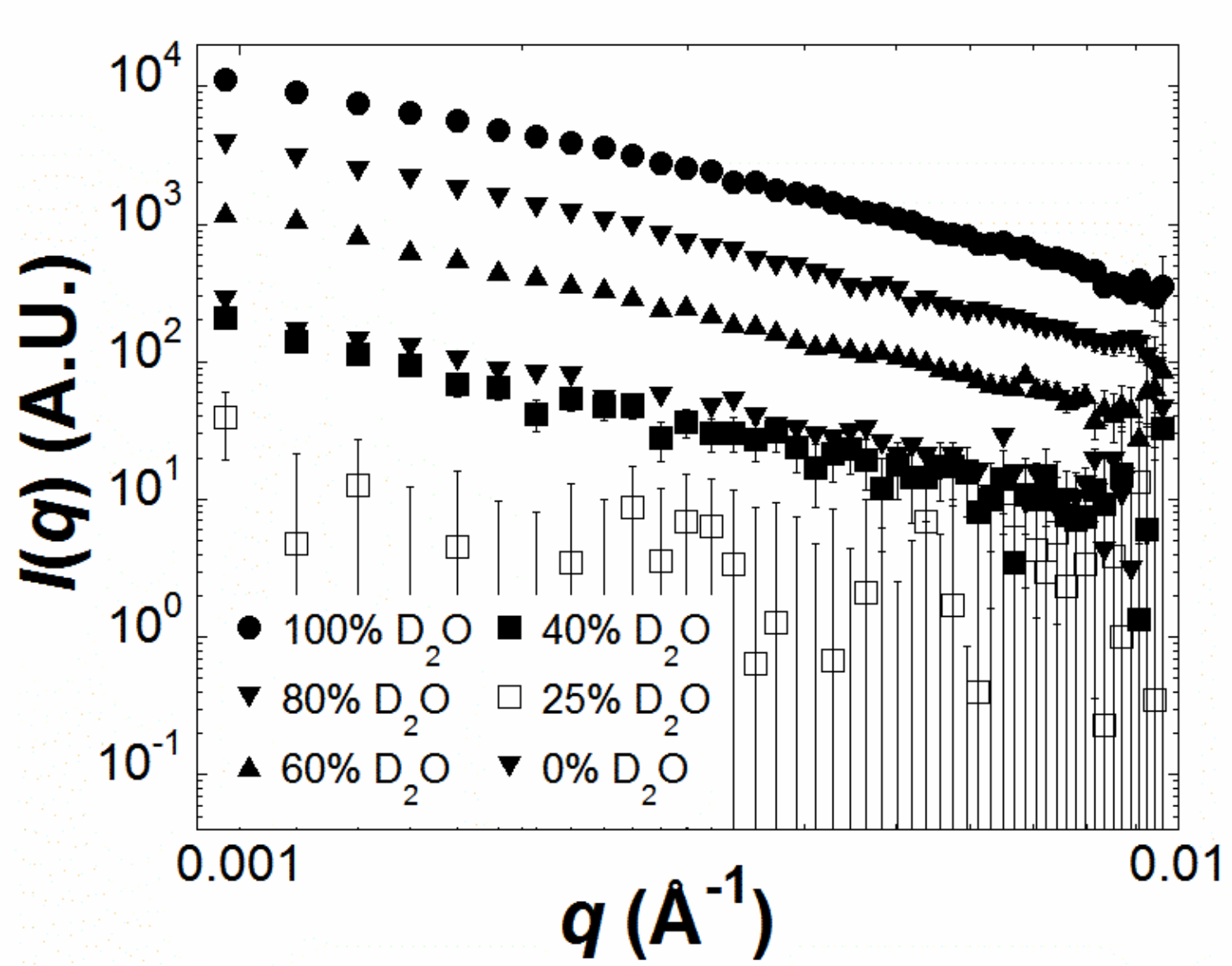
Lopez et al. *Energy and Enviromental Science*, (2010)

Contrast variation for SANS



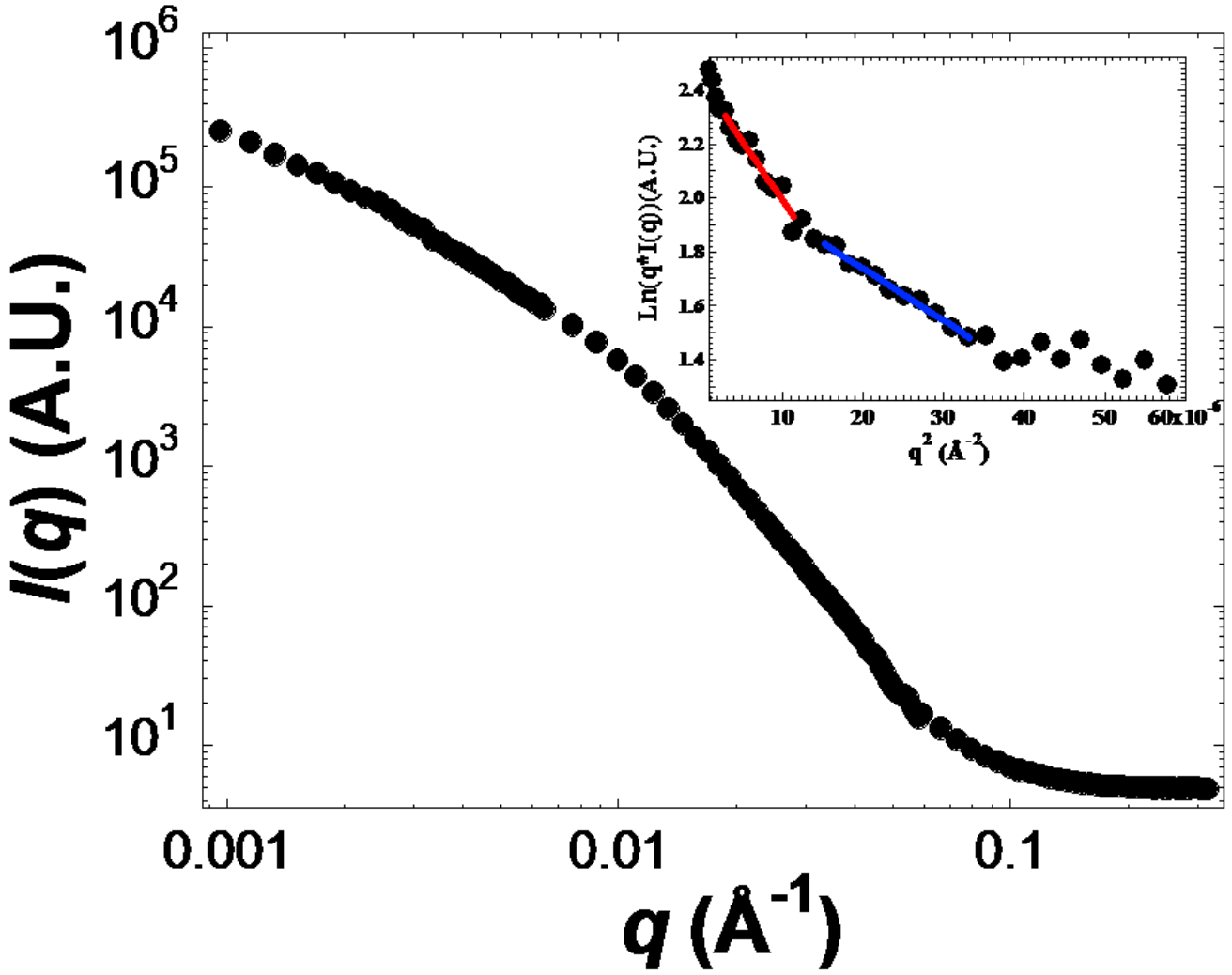
Matching Point: Lipids (Micelles), 5-25% D_2O; Proteins, 35-45% D_2O; Nucleic acids: 65-75% D_2O

SANS of Chlorosomes



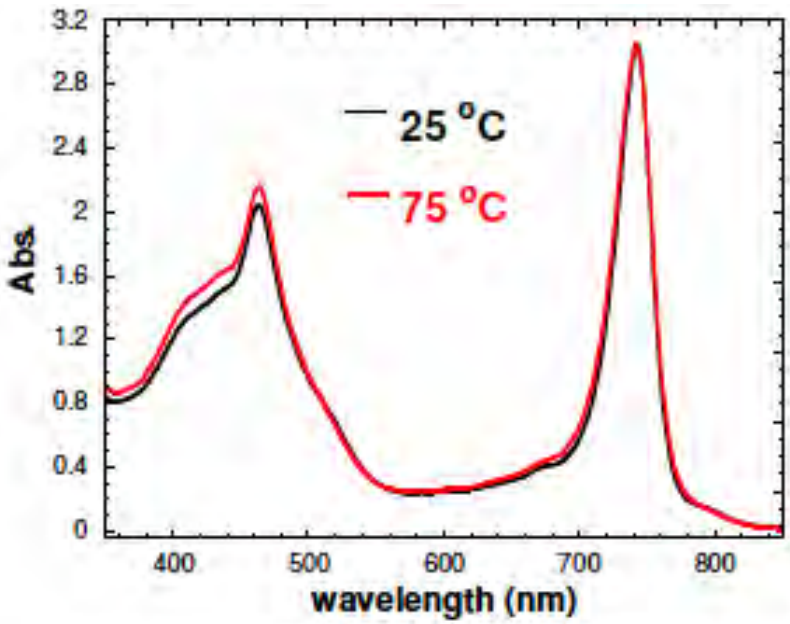
Chlorosome is a lipid-like particle

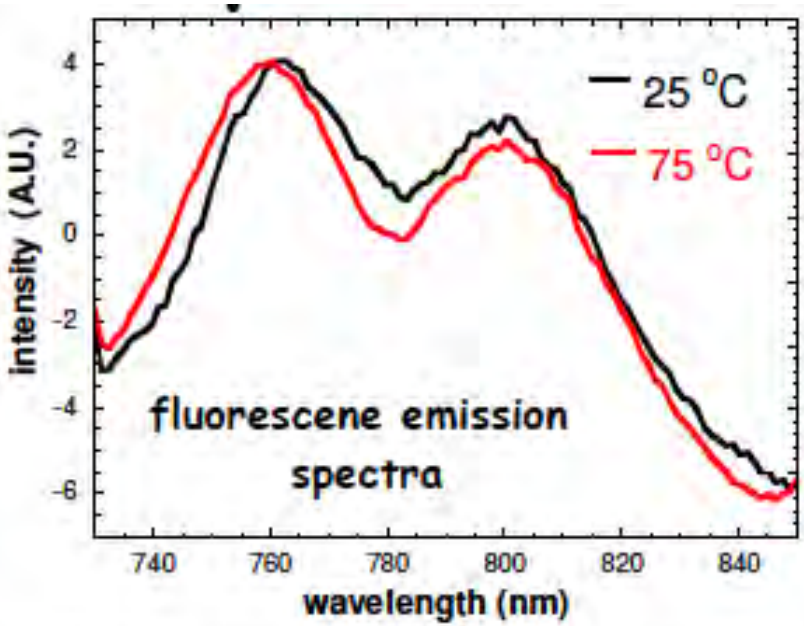
Guinier fits to chlorosome SANS

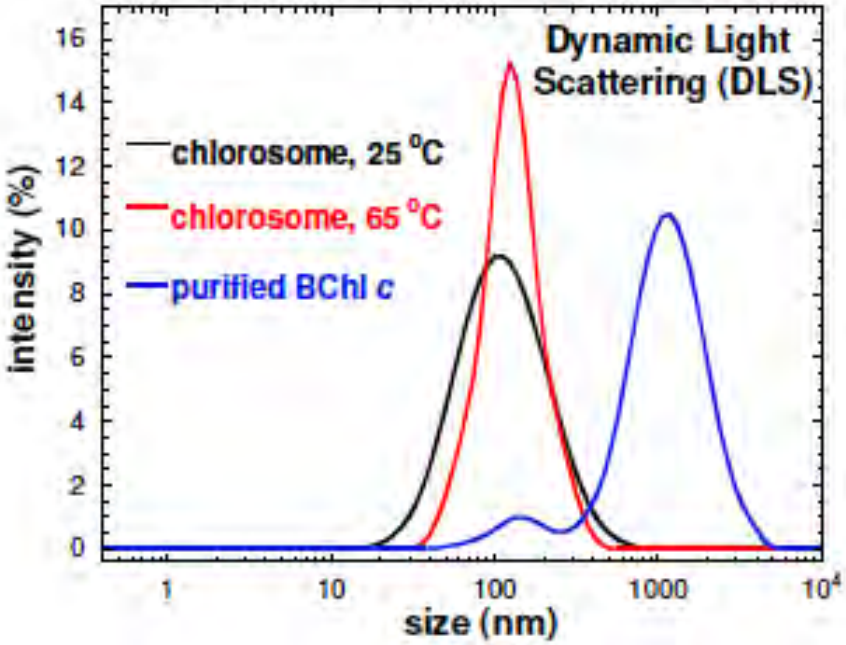


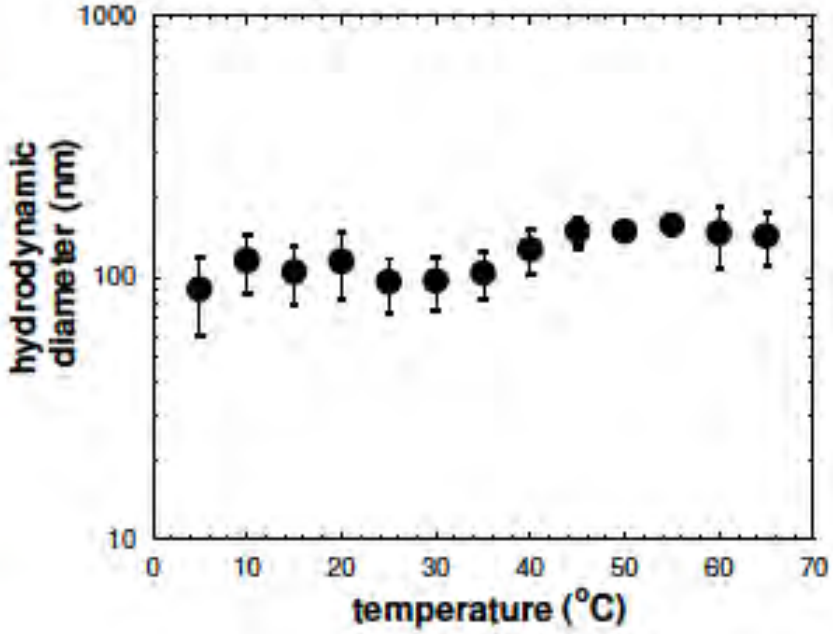
SANS for the chlorosome in 100% D_2O with two modified Guinier fits for rodlike particle shown in red and blue (inset)

Chlorosome stable up to 75 °C

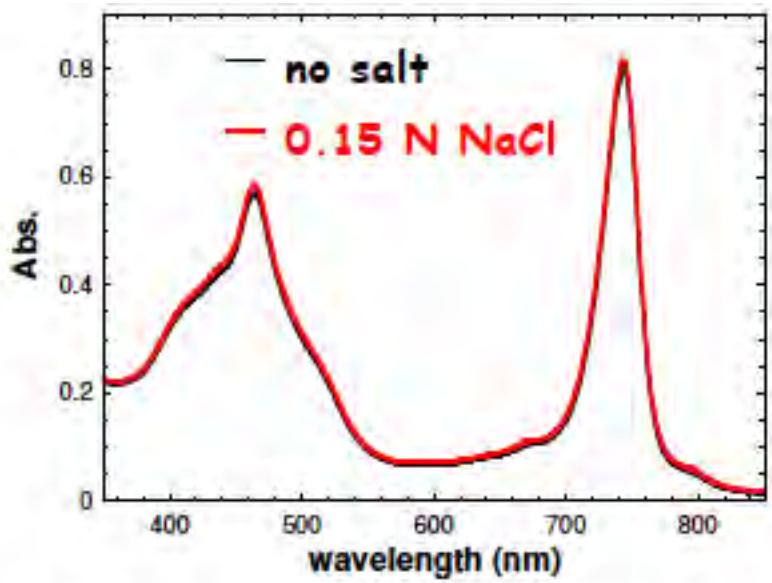


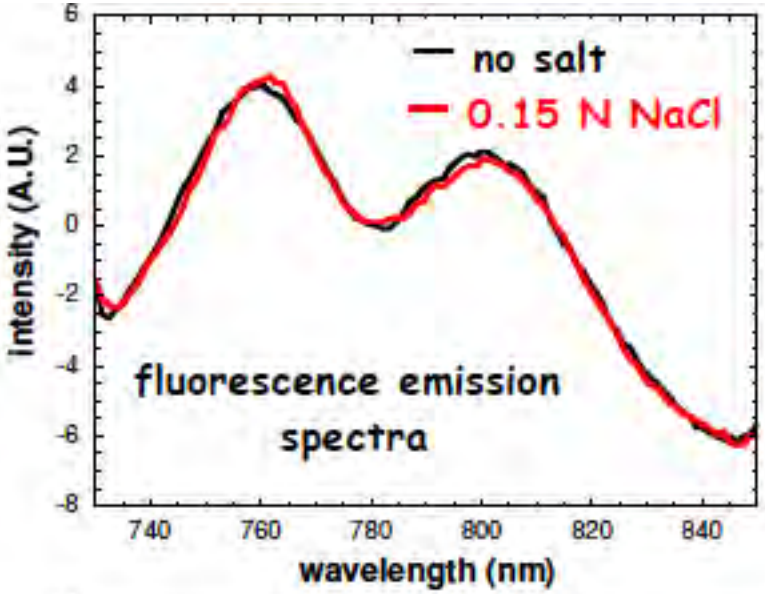


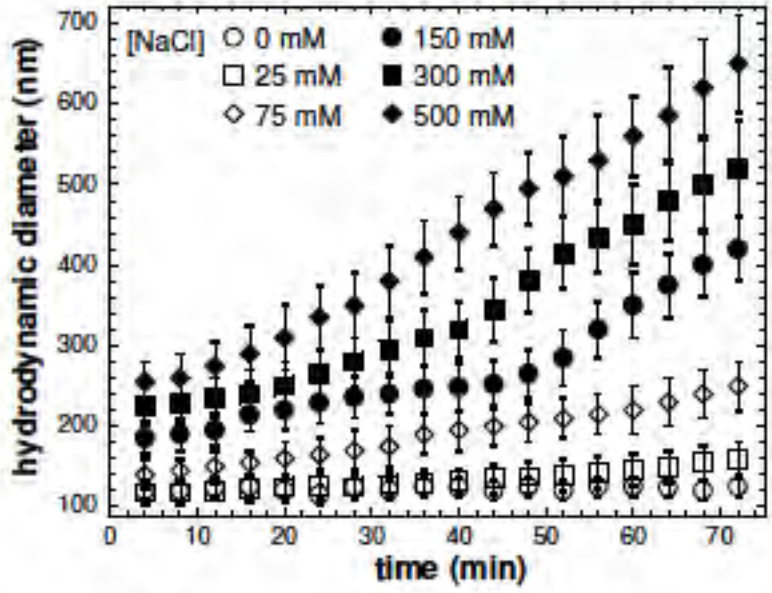


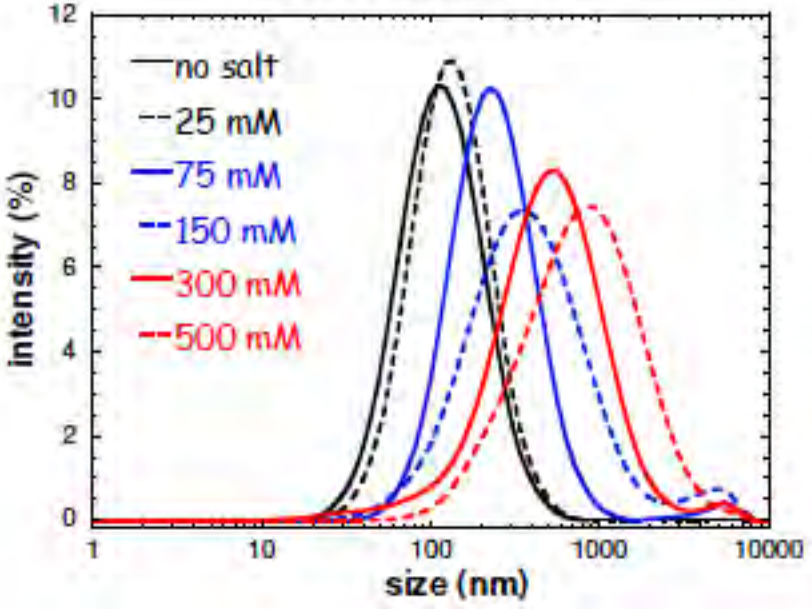


Large particle formed in high [NaCl]



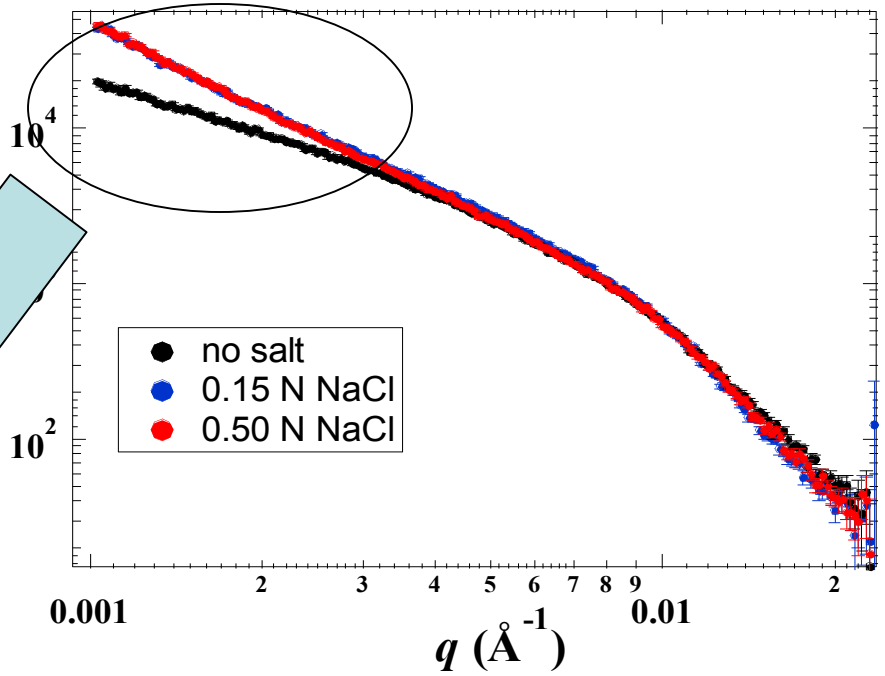


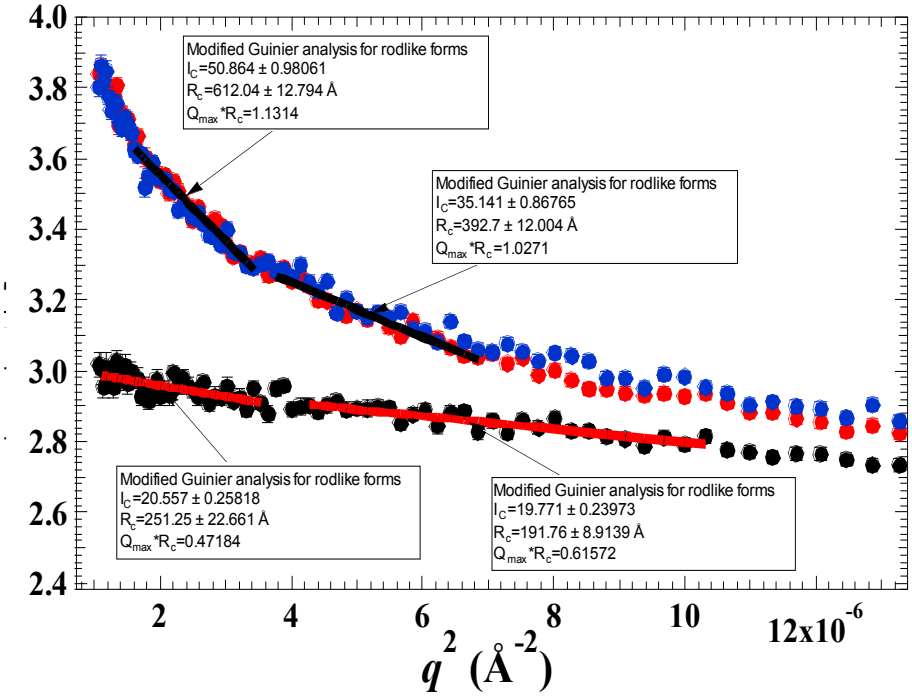




SANS of Chlorosomes

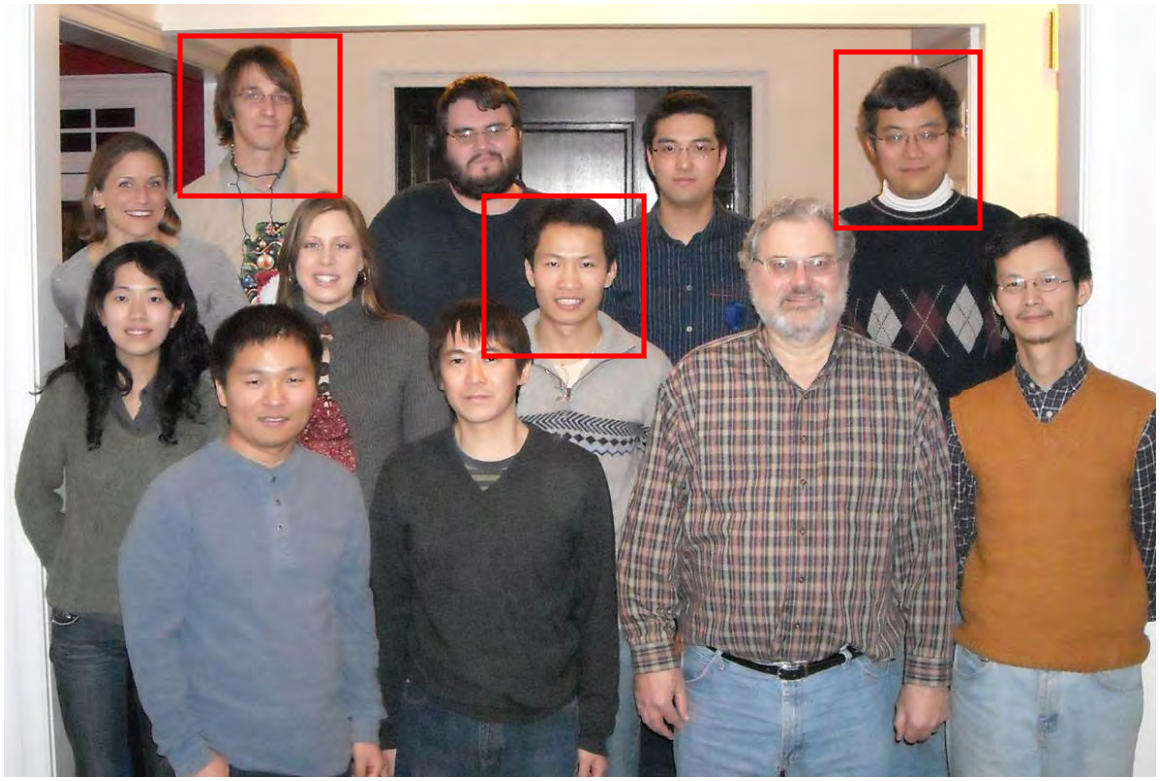
Modified-Guinier analysis (rodlike particle)





Much larger size of chlorosome particles at high salt suggested by SANS and confirmed by DLS

Wash. U. Research Group-2010



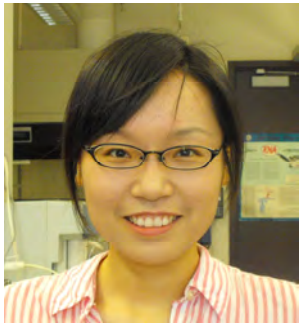
Darek Niedzwiedzki

David Bina

Mindy Prado

Connie Kang

Jeremy King



Jing Jiang

Front Row Xianglu Li, Jiro Harada, Bob Blankenship, Yueyong Xin,
Second Row Xinliu Gao, Jeanne Sheffield, Jianzhong Wen
Third Row Barb Honchak, Aaron Collins, Patrick Bell, Hai Yue, Joseph Tang
UG - Yamini Krishnamurthy, EJ Cho,